Gas Relationships

- **We will discuss:**
  - **Differences between liquids and gases**
  - **Stored energy of fluids**
  - **P-V-T relationships**
  - **Ideal gases**

HS-5050-4

There are differences between the two types of fluids

Liquids	**Gases**
Both obey Pascal's Law —— transmit pressure and motion	
Volume = f(T, P)	**Volume = f(T, P)**
Seeks own level and has a free surface	**Fills any container, regardless of shape**
Relatively incompressible	**Compressible***

***Most important for stored energy considerations:**

For water, volume reduction is ~1/3% for every 1000 psi pressure.

For helium, volume reduction depends on the pressure range, i.e., 30% from 2 ksi to 3 ksi, 10% from 7 ksi to 8 ksi.

HS-5050-5

Compressed fluids store energy . . . the more compressible the fluid, the more the energy

Liquid: PdV mechanical work

$$E = \frac{P_1^{\,2} V}{2B}$$

Gas: Isentropic expansion of a confined gas

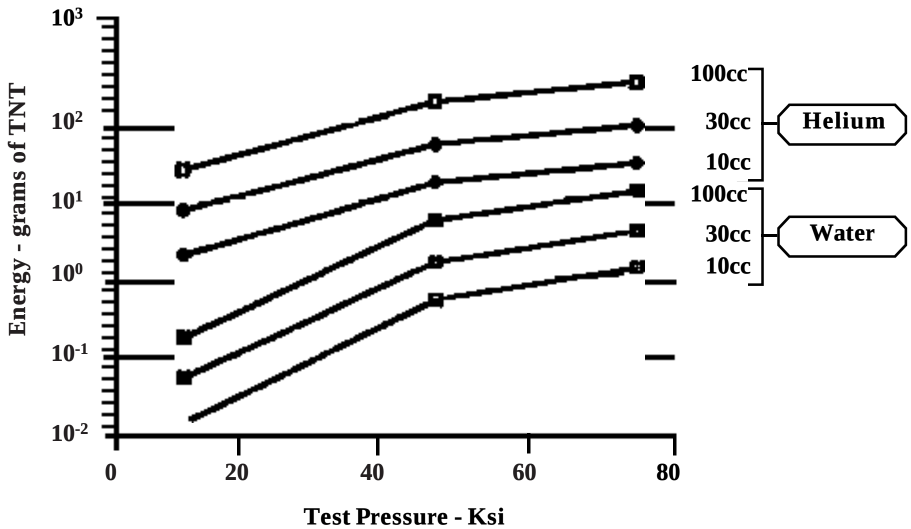
$$E = \frac{P_1 V_1}{K-1}\left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}\right]$$

Where:

E	=	stored energy		K	=	ratio of specific heats
P_1	=	MAWP		V	=	volume
P_2	=	atmospheric pressure		B	=	liquid bulk modulus

HS-5050-6

Stored Energy as a Function of Test Pressure



HS-5050-7

Why Gas?

(Would you consider liquid?)

HS-5050-8

HS-5050-9

Gas laws are relationships between pressure, volume, and temperature

- **Boyle's law (1660):** $\boxed{PV = C}$
  - **Pressure x Volume = Constant (@ T = C)**
- **Gay-Lussac's Law (1802):** $\boxed{\frac{V}{T} = C}$
  - **Volume depends on Temperature (@ P = C)**
- **Ideal Gas Law combines both:** $\boxed{\frac{PV}{T} = C}$
- **An Ideal Gas Law is officially written as:** $\boxed{PV = RT}$
  - **where the constant R depends on the type of gas involved.**

HS-5050-10

Consider the Ideal Gas Law written as:

$$\boxed{\frac{PV}{T} = C}$$

What this means is —— if a fixed quantity of gas is taken through any sort of process, then:

$$\left[\frac{PV}{T}\right] \text{@ initial condition} = \left[\frac{PV}{T}\right] \text{@ final condition}$$

$$\textit{or} \qquad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Note: Must use absolute values for Pressure (P) and Temperature (T).

HS-5050-11

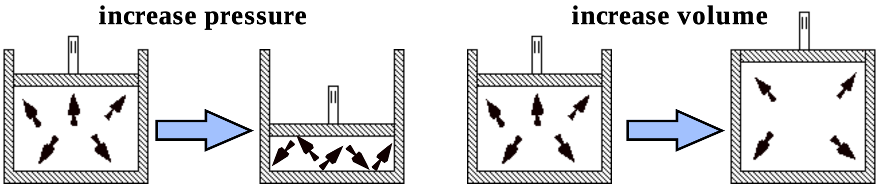
TNT Stored Energy Equivalents

multiply by → to obtain ↓	*Joules*	*Mega Joules*	*Ft. Lbs.*	*Grams TNT*	*KGrams TNT*	*Lbs. TNT*
Joules		*10^{6}*	*1.356*	*4.638×10^{3}*	*4.638×10^{6}*	*2.107×10^{6}*
Mega Joules	*10^{6}*		*1.356×10^{-6}*	*4.638×10^{-3}*	*4.638*	*2.107*
Ft. Lbs.	*7.376×10^{-1}*	*7.376×10^{5}*		*3.42×10^{3}*	*3.42×10^{6}*	*1.55×10^{6}*
Gram TNT	*2.157×10^{-4}*	*2.157×10^{2}*	*2.924×10^{-4}*		*10^{3}*	*454*
KGrams TNT	*2.157×10^{-7}*	*0.216*	*2.924×10^{-7}*	*10^{-3}*		*0.454*
Lbs. TNT	*4.746×10^{-7}*	*0.474*	*6.45×10^{-7}*	*2.2×10^{-3}*	*2.2*	

HS-5050-12

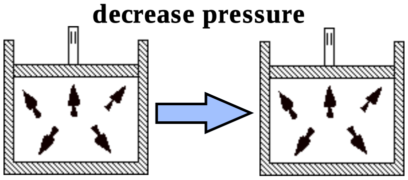
P–V–T relationships for a confined gas

At constant temperature, increase pressure | **At constant pressure, increase volume**



P ( ) V ( ) = C **COMPRESS** | **V ( ) / T ( ) = C** **HEAT**

At constant volume, decrease pressure



P ( ) / T ( ) = C **COOL**

HS-5050-13

Example Problem 1

A cylinder of dry nitrogen is received from a vendor. The temperature of the nitrogen is 70°F, and the pressure inside of the cylinder is 2,250 psig. An employee inadvertently stores the cylinder too close to a radiator, and 8 hours later, the nitrogen is heated to 180°F.

What is the new pressure inside the cylinder?

Initial	**Final**
$P_1 = 2{,}250 + 15 = 2{,}265$ psia	$P_2 = ?$
V_1 = constant	$V_2 = V_1$ = constant
$T_1 = 70 + 460 = 530$ R	$T_2 = 180 + 460 = 640$ R

$$\left(\frac{PV}{T}\right)_1 = \left(\frac{PV}{T}\right)_2 \longrightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P_2 = \left(\frac{P_1}{T_1}\right) T_2 = \left(\frac{2{,}265 \text{ psia}}{530 \text{ R}}\right) 640 \text{ R} = 2{,}735 \text{ psia } \textit{or } 2{,}720 \text{ psig}$$

HS-5050-14

Example Problem 2

How many standard cubic feet (SCF)* are contained in this cylinder?

Given:

$P_1 = 2{,}265$ psia	$P_2 = 14.7$ psia
$T_1 = 70$°F	$T_2 = 70$°F
$V_1 = 1.5$ ft^3	$V_2 = ?$ SCF

Solution:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{2{,}265 \times 1.5}{14.7} = 231 \text{ SCF}$$

****SCF: One cubic foot of gas at "standard conditions" of temperature and pressure; i.e., average sea level conditions — 70°F and one atmosphere (14.7 psia).***

HS-5050-15

Gases at higher pressures do not obey the Ideal Gas Law

(PV = RT)

A correction factor —— Amagat Number instead of pressure may be applied to account for this effect:

$$\frac{\rho_a V}{T} = R_1 T$$

Hence:

Ideal Gas	**becomes**	**Actual Gas**
$\frac{PV}{T} = C_1$		$\frac{\rho_a V}{T} = C_2$

Gas calculations dealing with non-ideal gases (using amagat) will be discussed in H.S.-5060

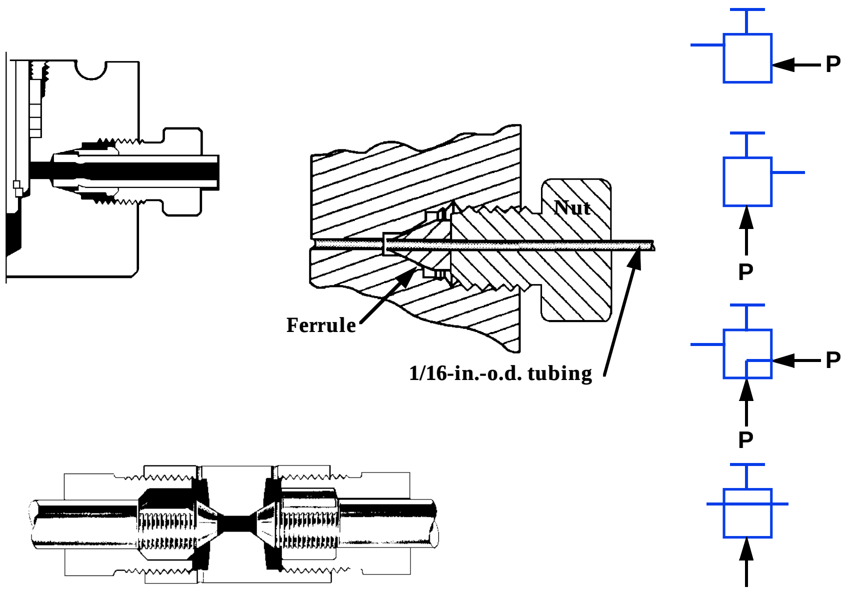
HS-5050-16

Summary Points

- **Compressed liquids store significant energy.**
- **Gases store much more energy than liquids.**
- **Pressure test with liquids whenever possible.**
- **Gas calculations involve relationships between pressure, temperature, and volume.**
- **Real gases do not obey the Ideal Gas Law above a few thousand psia.**

HS-5050-17

High Pressure Fittings and Equipment



HS-5050-18

High Pressure Fittings and Equipment

- **We will discuss**
  - **Bite-type fittings**
  - **Coned and threaded connections**
  - **Glands and collars**
  - **High pressure valve types, stem assemblies and ordering information**

HS-5050-19

Bite-type Fittings

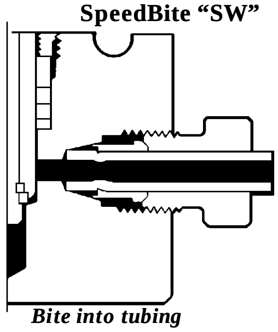
- **AE low pressure (SpeedBite) connections**
  - **Available for 1/8” through 1/2” tubing.**
  - **Use a single sleeve that “bites” into tubing, creating a shoulder to support end load.**
  - **Rated to 11,500 psi.**
  - **Consider tubing hardness.**
  - **Reference manufacturer’s assembly instructions.**
  - **Wall thickness:**

    1/8” tube – .020” to .032”

    1/4” tube – .028” to .062”

(refer to manufacturer literature for other tube sizes)

SpeedBite “SW”



Bite into tubing exaggerated for clarity

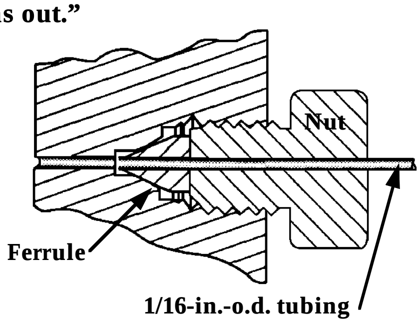
HS-5050-20

Bite-type Fittings, continued

- **HIP Taper Seal Connections**
  - **Used widely on 1/16” and 1/8” tubing.**
  - **Employs a single sleeve that “clamps” onto tubing.**
  - **Rated to 15,000 psi for 1/16” and 1/8” tubes.**
  - **Using a thread lubricant for initial make-up, the assembly is properly made when nut “bottoms out.”**
  - **Wall thickness:**

    1/16” tube – .017” to .028”

    1/8” tube – .032” to .053”



HS-5050-21

Coned and threaded connections

- Coning provides line contact sealing resulting in a minimal seal area.

$$P = \frac{F}{A}$$

- Threading positively locks tube to fitting using a collar.
  - Excellent choice for re-makes
  - Very reliable in thermal cycling
  - Ease of serviceability

HS-5050-22

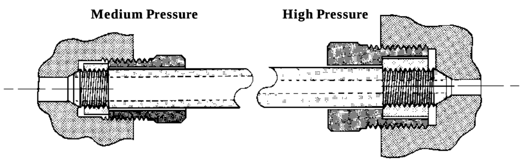
Coned and threaded connections, continued

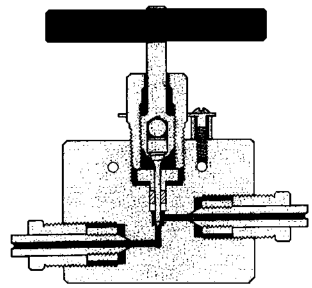
- Medium pressure (Slimline) connections are used for pressure to 20,000 psi

- High pressure connections employ two different connections depending on range:
  - 30,000 psi to 60,000 psi high pressure
  - 100,000 psi to 150,000 psi high pressure

HS-5050-23

Coned and threaded connections, continued





20,000 psi medium pressure vs. 60,000 psi high pressure

150,000 psi high pressure

Caution: Tubing, collars and gland nuts are NOT interchangeable for medium and higher pressure connections.

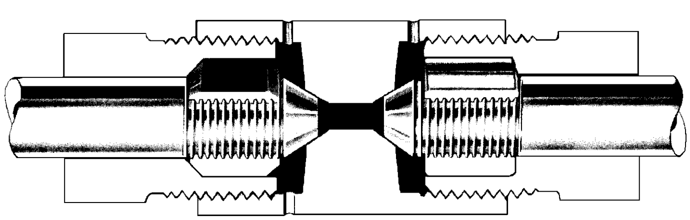
(Pictures courtesy of HIP)

HS-5050-24

Coned and threaded connections, continued

Another word of caution regarding gland nuts, collars and plugs (for high pressure connections only):

- **Old connections have 90° angle contact, while newer designs have 45° angle contact. Therefore, be certain that you inspect components and do not interchange them with each other.**



HS-5050-25

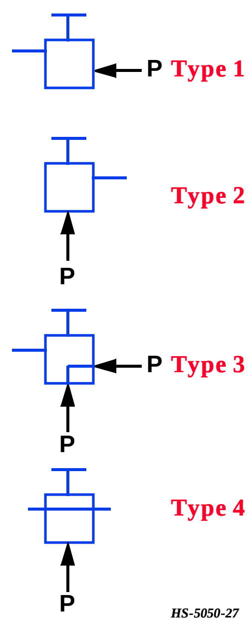
High Pressure Fittings

- The threads carry the load
- Force = Area x Pressure
  - Use the smallest seal to minimize force
- Provide pressure relief/leak detection (weep holes)

HS-5050-26

Common Valve Types

- Two port valves
  - Type 1: Straight Through Valve
  - Type 2: Angle Valve
- Three port valves
  - Type 3: Two Ports to Pressure
  - Type 4: One Port to Pressure

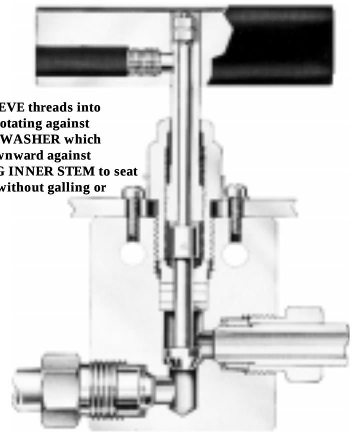


HS-5050-27

Most high pressure valves employ non-rotating stems

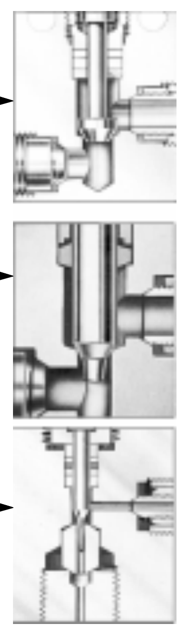
- Avoid leakage because galling and scoring is minimized.
- Similar materials can be used for stem and seat which results in better corrosion resistance.
- Remachinable bodies provide long service life.

STEM SLEEVE threads into BONNET rotating against BEARING WASHER which pushes downward against FLOATING INNER STEM to seat positively without galling or scoring.



Consider stem types

- **Vee Stem**
  - On/Off service. No throttling effect.
- **Regulating Stem**
  - More accurate flow control than vee stem. Good general purpose for throttling and shut-off.
- **Micro Metering Stem**
  - Precise control of small flows. Requires a shut-off valve upstream.



HS-5050-29

DISASSEMBLY, INSPECTION, CLEANING, AND ASSEMBLY OF AUTOCLAVE 30VM VALVES

(See Appendix A)

HS-5050-30

AE valves with FEMALE connections

30VM	4	07	4

VALVE SERIES

30VM			

30VM = AE series 30VM high pressure valves to 30,000 psi.

CONNECTION O.D. TUBE SIZE

	4		

4 = 1/4”

STEM TYPE

		07	

07 = Non-rotating VEE stem (on-off service)

BODY PATTERN

			4

4 = Three-way, one port to pressure

HS-5050-31

Pumps and Compressors

We will discuss . . .

- **Batch Compressors**
- **Steady-State Operation**
- **Types of Drivers**
- **Intensifiers/Diaphragms**

HS-5050-32

Classification of Pumps* and Compressors*

- **Rotary – vanes, jets, turbines, etc.**
- **Reciprocating – positive displacement, i.e., gas trapped in fixed volume is compressed and forced out.**
- **Most high pressure applications now employ reciprocating type.**

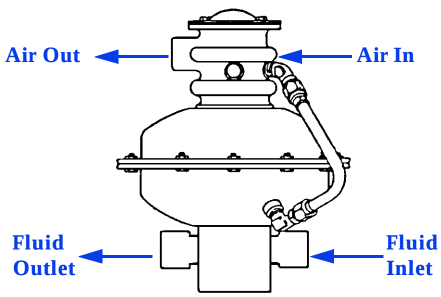
***Pumps move liquids.**

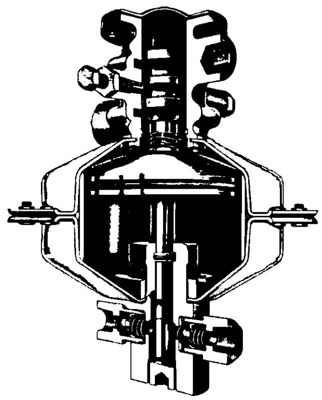
***Compressors move gases.**

HS-5050-33

Early Gas Compression Involved a "Batch Process"

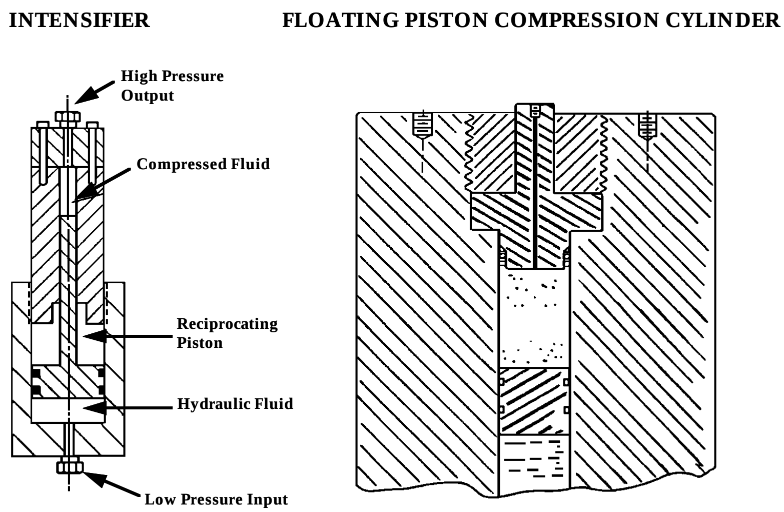
- **Air-driven oil pumps were available to provide the driver fluid.**





HS-5050-34

2 Types of Pressure Amplifiers Were Used



- **A driver pump combined with one of these driven elements provided "batch compression."**

HS-5050-35

Steady-State (Reciprocating) Operation

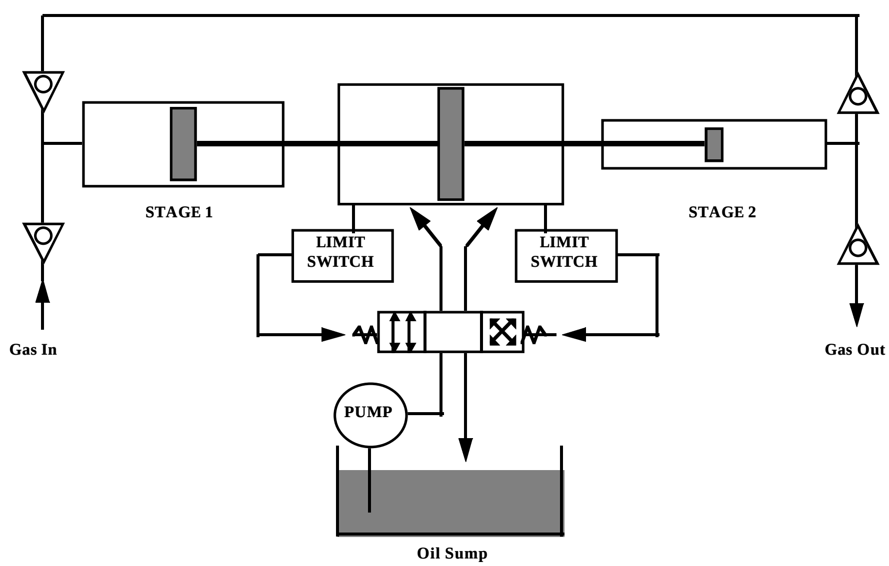
- Requires – cyclic pressurization of driver fluid
  - Inlet and outlet check valves
- Most modern compression equipment involves the use of intensifiers or diaphragms with various combinations of "driver to driven"

Driver	Driven	Example
Air	Liquid or Gas	Haskell
Air → Oil	Gas	Newport*
Elec. → Oil	Gas	Corbin*
	Gas	PPI*
	Liquid or Gas	Hydro-pac

*Diaphragm

HS-5050-36

Typical Driver-Shifter Arrangement



Other shifting methods include air distribution valves and motor-driven cranks.

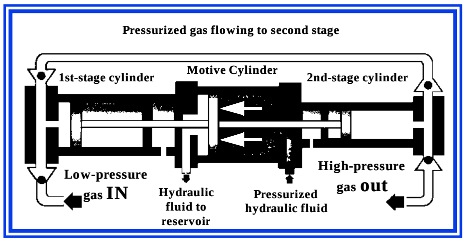
HS-5050-37

Actions and Stages

- Because liquids are relatively incompressible, many pumps operate with only one stage of compression.
- Because gases are highly compressible, most compressors require multiple stages of compression.
- Double acting drivers, i.e., mirror-image opposed action, are in common use.
- Hence:
  - pumps tend to be double acting single stage (DASS).
  - compressors tend to be double acting two stage (DA2S)

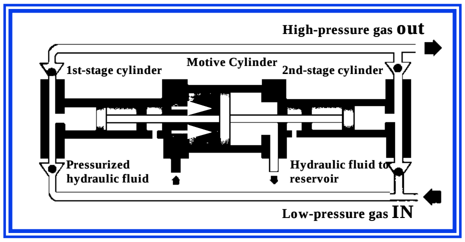
HS-5050-38

Typical Double-Acting Operation

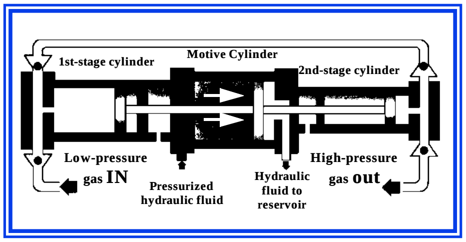


Stage I Compression

DA2S



DASS

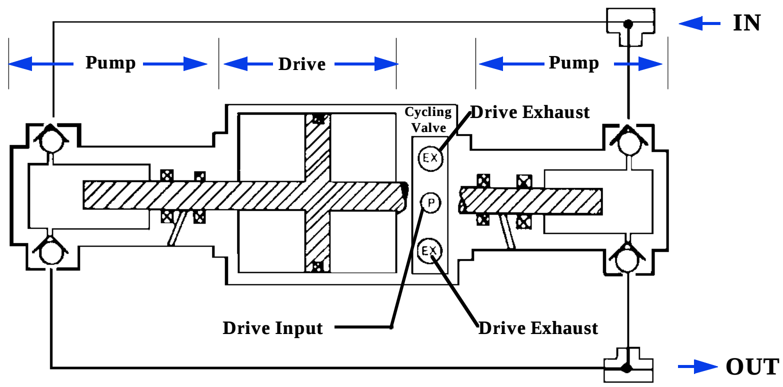


Stage II Compression

Picture courtesy of Hydro-Pac

HS-5050-39

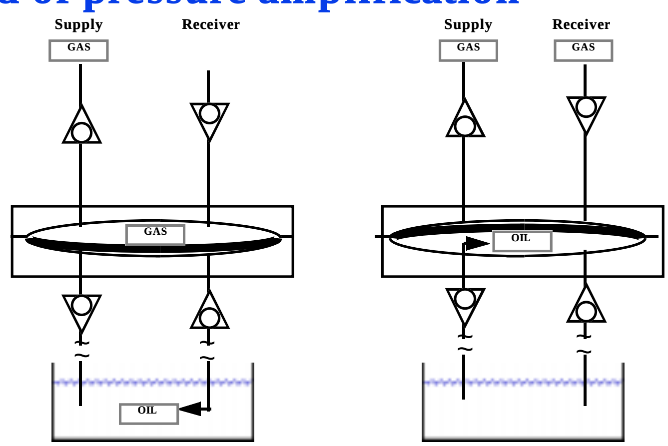
An Air-Driven DASS Gas Compressor



Picture courtesy of Haskell

HS-5050-40

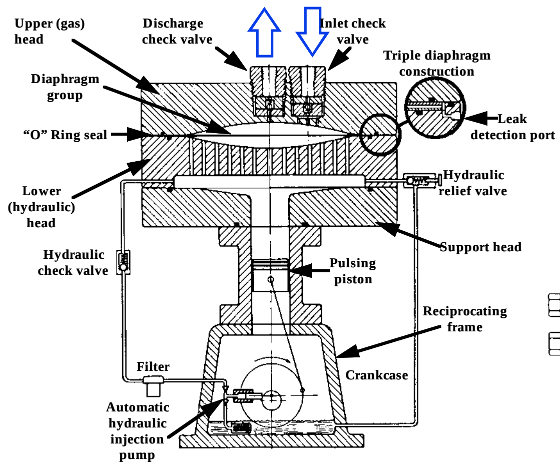
Diaphragm compressors provide an alternate method of pressure amplification



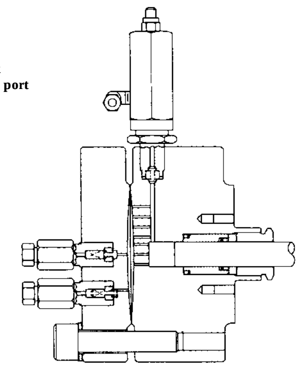
- **Sandwich of flexible diaphragms is contained and clamped in a double concave cavity.**
- **Diaphragms separate hydraulic driver fluid from gas to be compressed.**
- **Pulsating driver pressure flexes diaphragm combination; cavity alternately intakes, compresses and exhausts each fluid.**

HS-5050-41

Two Types of Diaphragm Compressor Drives



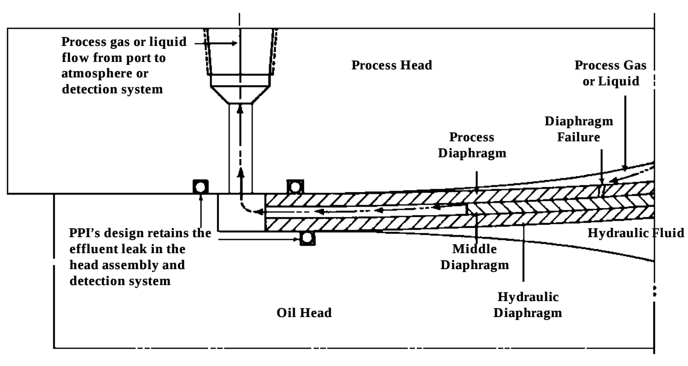
Oil-driven via
electric motor crank

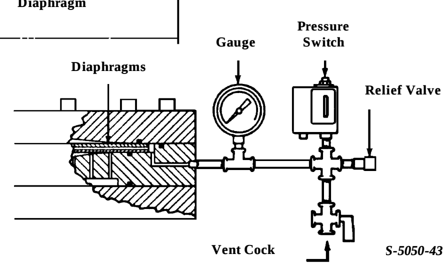


Oil-driven via air-
operated plunger pump

HS-5050-42

Triple Diaphragm Construction* provides a method of leak detection (Diaphragm failure)



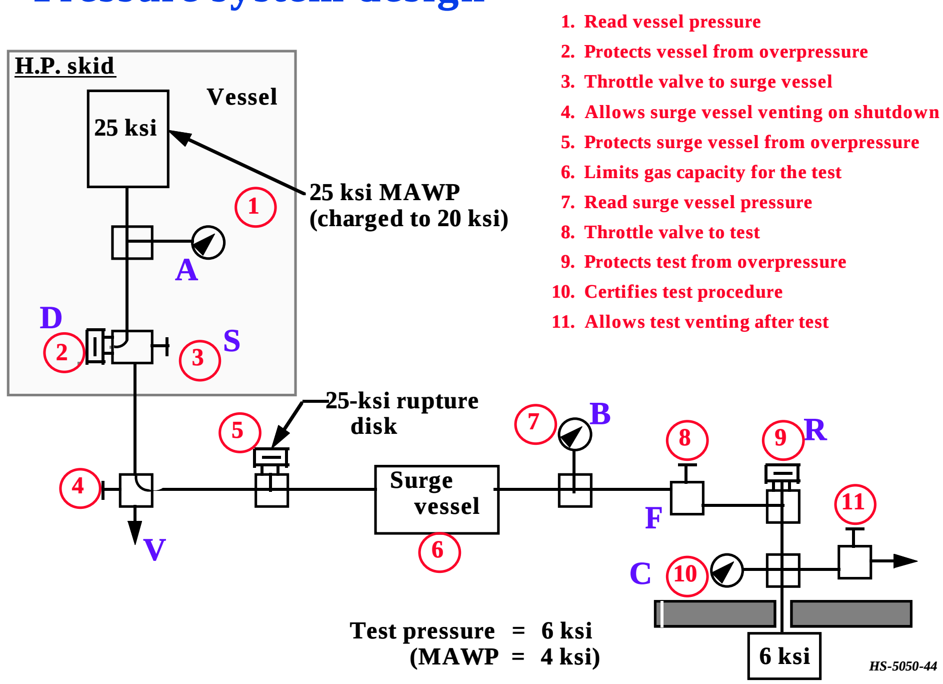


Leak Detection System

Picture courtesy of PPI

S-5050-43

Pressure system design

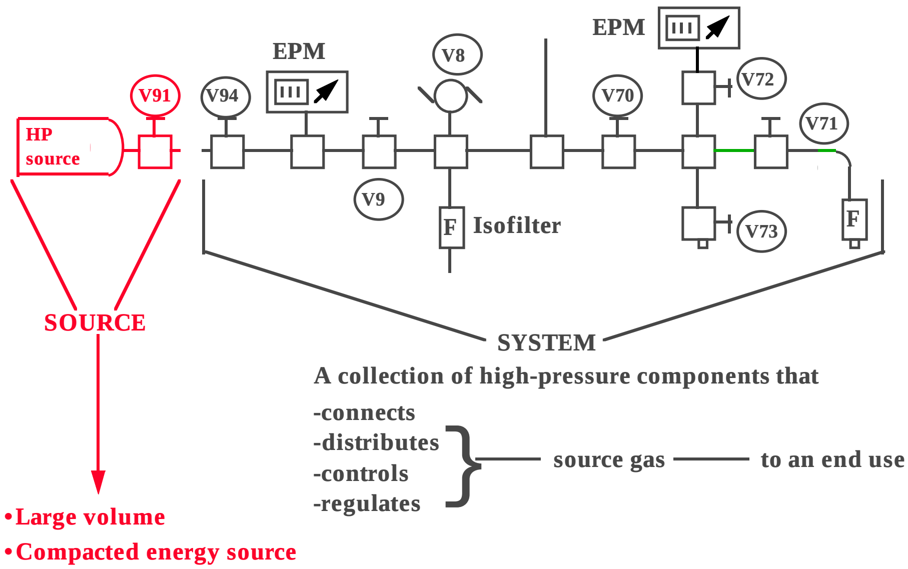


We will discuss:

- Sources vs. systems
- Ground rules for pressure systems
- High pressure system components
- Elements of a basic high pressure system
- Pressure system design problem

HS-5050-45

There are pressure sources, and there are pressure systems

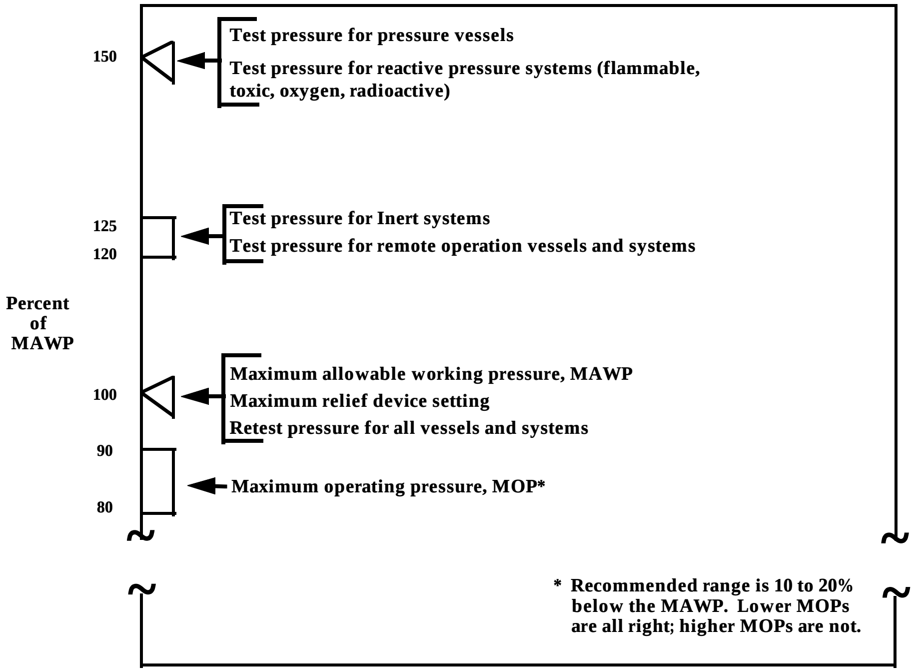


HS-5050-46

Use Readable Schematics!

- **Locational Schematic:**
  - **–Describes component location (sometimes).**
  - **–Often difficult to understand.**
- **Functional Schematic:**
  - **–No (or few) crossed lines.**
  - **–Best way to understand how it works.**

HS-5050-47



HS-5050-48

Some pressure system ground rules:

- Assembly drawings should contain the MAWP.
- The MAWP of a system is determined by the weakest component in the system.
- Pressure tests for systems are different than for sources.
- Sources are not allowed to over-pressure systems:

1. Limit source to the rating of the weakest system component.
2. Use a pressure-relief device if the source cannot be limited.
3. Pressure regulators are not adequate as limiters.

HS-5050-49

DO's and DON'Ts for relief devices

- No valve between relief and component.
- Setting may not exceed lowest component MAWP.
- Don't point relief at people.
- Relief must not restrict gas flow.
- Reliefs set by authorized people only.
  (Recommended every (3) three years)

HS-5050-50

High-Pressure System Components

- **Pipe/tubing**
  - Pressure rating must be equal to or greater than system MAWP
  - ANSI B31.1 pressure rated
  - Pipe fittings: MAWP = 150 psi or stamped rating, or manufacturer's reference
- **Hose**
  - Only where required
  - Shortest lengths, minimum bends, tie down ends
  - No toxics/radioactives

HS-5050-51

High-Pressure System Components, continued

- **Valves/fittings**
  - **Pressure rating must be equal to or greater than system MAWP**
  - **Seat/stem/seal material compatibility**
  - **Valve-stem adjustment/locked**

- **Pressure gauges**
  - **Full scale = 2 X MAWP (1.2 minimum)**
  - **Material compatibility**
  - **Blow-out back or shield**
  - **Protect from surges w/damper, etc.**
  - **Beware of contamination by calibrating oil**
  - **Provide relief protection**

HS-5050-52

Example Tubing Chart

Note: MAWP values shown to be applied to example problem only.

O.d. (in.)		I.d. (in.)	Nominal wall	MAWP	
Nominal	Tolerance	Nominal	Tolerance	thickness (in.)	(psig)
1/16	0.0645/0.0625	0.005	0.006/0.004	0.028	60,000
1/16	0.0645/0.0625	0.042	0.044/0.040	0.010	20,000
1/8	0.128/0.125	0.085	0.087/0.083	0.020	20,000
1/8	0.128/0.125	0.093	0.095/0.091	0.016	15,000
1/4	0.249/0.243	0.083	0.083/0.078	0.084	55,000
1/4	0.254/0.250	0.210	0.212/0.208	0.020	3,000
5/16	0.311/0.305	0.062	0.062/0.057	0.125	100,000
3/8	0.374/0.368	0.125	0.125/0.120	0.125	60,000
3/8	0.379/0.375	0.305	0.308/0.302	0.035	3,500
1/2	0.504/0.500	0.402	0.405/0.399	0.049	59,804
9/16	0.561/0.555	0.187	0.187/0.182	0.189	60,000
9/16	0.561/0.555	0.312	0.323/0.317	0.125	20,000
3/4	0.749/0.743	0.437	0.437/0.432	0.157	25,000
3/4	0.754/0.750	0.620	0.623/0.617	0.065	3,500
1	0.999/0.993	0.562	0.562/0.558	0.219	20,000
1	0.999/0.993	0.687	0.687/0.682	0.157	10,000

** Based on a theoretical burst pressure safety factor of 2 or higher.*

HS-5050-53

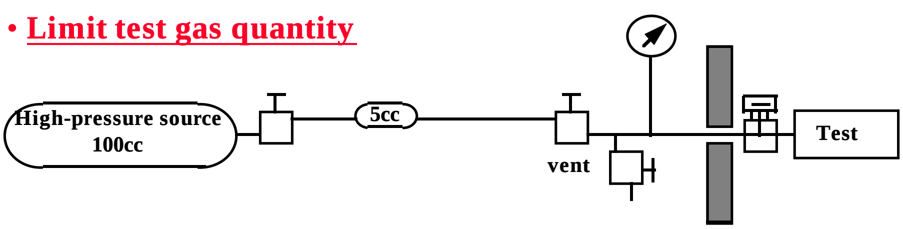
Foreign particles must be kept out of a high-pressure system

- **Cap all unused lines.**
  - **Uncap to use**
  - **Recap after use**
- **Use particulate filters.**
- **Inspect all components before use.**
- **Air flush, degrease, and deburr as required.**

HS-5050-54

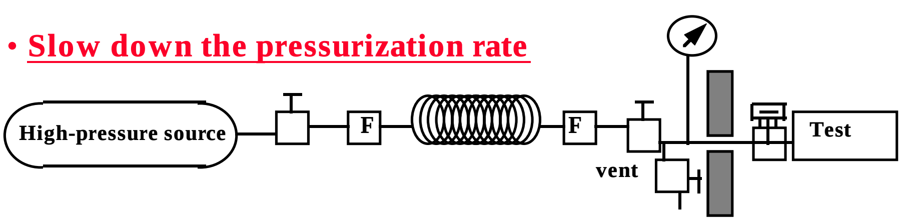
Keep control of the gas-transfer process

- **Limit test gas quantity**



Use a piggyback

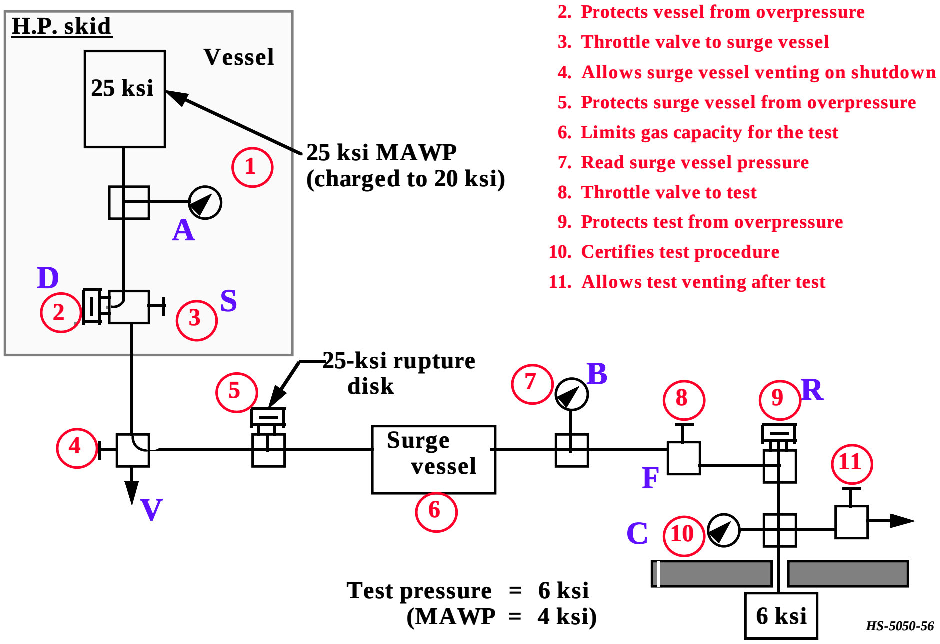
- **Slow down the pressurization rate**



Use a fill delay

HS-5050-55

Pressure system design



1. Read vessel pressure
2. Protects vessel from overpressure
3. Throttle valve to surge vessel
4. Allows surge vessel venting on shutdown
5. Protects surge vessel from overpressure
6. Limits gas capacity for the test
7. Read surge vessel pressure
8. Throttle valve to test
9. Protects test from overpressure
10. Certifies test procedure
11. Allows test venting after test

Circle the best choice:

Gauge A range (ksi)	Gauge B range (ksi)	Gauge C range (ksi)	Rupture disk D rating (ksi)
0 – 50	0 – 50	0 – 4	30
0 – 25	0 – 20	0 – 2	27.5
0 – 20	0 – 10	0 – 6	25
0 – 10	-30" – 1000 psi	0 – 10	6.6

Pressure rating of valves S&V (ksi)	Pressure rating of valve F (ksi)	Relief valve R setting (ksi)	Size of MEL 681* tubing between skid & valve F
3	4	7.5	9/16 o.d. – 0.312 i.d.
30	6	9.0	1/4 o.d. – 0.083 i.d.
20	15	7.0	1/8 o.d. – 0.085 i.d.
15	30	4.8	1/16 o.d. – 0.042 i.d.

HS-5050-57

Summary Points

- **Pressure systems:**
  - **Usually store less energy than vessels.**
  - **Are tested differently than vessels.**
  - **Are limited by the weakest component.**

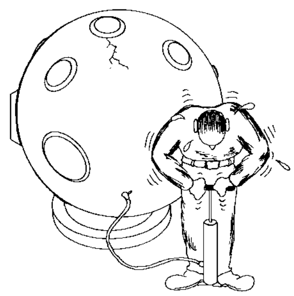
- **Use a relief device if source MAWP is greater than system MAWP.**

- **Give careful consideration to the selection of:**
  - **Pipe/tubing**
  - **Gaging**
  - **Reliefs**
  - **Valving**

HS-5050-58

HS-5050-59

High Pressure Hydrogen Safety



HS-5050-60

We will discuss:

- **Ignition characteristics and sources**
- **Hazardous atmospheres per fire/safety codes**
- **Safe designs**
- **Hardware/equipment for hydrogen**
- **Enhancing hydrogen safety**

HS-5050-61

Hydrogen

- **Ignites in air in two ways:**
  - **Burns at 4% to 75% concentrations**
  - **Detonates at 18% to 59% concentrations**
- **On ignition, energy release is 20 – 30 times its PV energy**
- **When confined, detonates (explodes) rather than burns**
- **Low ignition-energy requirements . . .**
  - **Approximately 20 microjoules (1/10 of gasoline/air mixtures)**
  - **Thermal Threshold = 560°C**
  - **Electrical Threshold = 200MA @ 24V DC**

HS-5050-62

Concern is spark-producing ignition sources in an air environment.

- **Spark-producing electrical equipment; i.e., switches, relays, motors, lights.**
- **Electrostatic charge with friction heating; i.e., rapid decompression.**

(Uninterrupted steady-state electrical gear generally not a concern.)

HS-5050-63

Several fire-safety codes categorize hydrogen-safety environments.

- **National Fire Protection Association (NFPA)**
  - —**NFPA 50A:** Gaseous hydrogen at consumer sites
  - —**NFPA 70:** National Electric Code (NEC)
  - —**NFPA 496:** Purged and pressurized enclosures for electrical equipment in hazardous locations

HS-5050-64

Classification of Hazardous Atmospheres

Class	Division	Group
I Gases - Vapors	1. Normally hazardous	A. Acetylene B. Hydrogen C. Ethyl ether, etc. D. Gasoline, alcohol, propane, etc.
II Combustible dusts	2. Not normally hazardous (Only by accident or breakdown)	E. Metal dusts F. Carbon, coal dust G. Floors, grain dusts

from NFPA 70

HS-5050-65

Safe design includes:

- Vent stacks permanently designed into plumbing systems to allow controlled remote, elevated venting – check-valve protected.

- Guaranteed convective venting of the test area via forced airflow or natural convection.

- Minimal to no electrical equipment located in the hydrogen area.

HS-5050-66

Safe design, continued

- Elimination of trapped dead air spaces at elevated locations in test area.
- Minimize high pressure gas quantities in enclosed use areas . . . sources located outside whenever possible.
- Roof or one wall as blowout protection (lightweight material or lightly attached); desired vent area per work volume is 1 ft^2 / 30 ft^3.

HS-5050-67

Hardware/equipment considerations

- Ensure against hydrogen embrittlement . . . use only hydrogen-compatible materials.
- Spark producers must be purged with inert gas.
- Purge enclosures must have adequate vent capacity.

HS-5050-68

Hardware/equipment considerations, continued

- Above 3 ksi, bourdon-tube pressure gauges should be considered manned area unsafe.
- Explosion Proof (EP) rated electrical equipment involves ignition containment. Does not address Groups A or B.

Example = "EP" electric motors

Class I, II, Group B required.

Class I, II, Group D, E, F, G available.

HS-5050-69

Intrinsic Safety (IS) is based on ignition prevention

- **Limits electrical energy available for ignition.**
- **Primary application is electrically operated (solenoid) valves.**
- **Requires two elements -**
  - **Low current draw solenoid (30 to 60 MA) with diode protection.**
  - **Interface (barrier) circuit for electrical isolation, i.e., zener diodes or isolation transformers.**
- **Commercially available - blue wiring signifies "IS".**

HS-5050-70

Hydrogen safety is enhanced when:

- **Gas handling is done remotely whenever possible.**
- **Secondary containment is used for all "high risk of failure" operations.**
- **Secondary containments are made "air free"; i.e., evacuated, then inert gas backfilled.**
- **Volumes under test are minimized by slugging.**

HS-5050-71

Hydrogen safety is enhanced, continued

- Hydrogen is not brought out of remote test areas into manned control areas; i.e., use remote pressure-gauging via transducers.
- Prior to use, all air is removed from all wetted plumbing by evacuation or purge techniques.
- Permanent electrical equipment is "EP" rated.
- Temporary experimental electrical equipment operation is allowed after risk evaluation.

HS-5050-72

Administrative controls should include:

- Documentation that certifies the mechanical integrity of the system.
- Documentation that addresses hazards, safety controls, and methods of operation.
- Procedures that define the operation.
- Strict control of the physical area during gas handling operations; i.e., barriers, cell locks, signs.
- Trained and knowledgeable personnel to perform the operation.

HS-5050-73

APPENDIX A
Disassembly, Inspection, Cleaning and Assembly of Autoclave 30VM Valves

Disassembly

1. Make sure the valve stem is backed off the seat (to prevent possible damage to the stem or seat).
2. Remove locking device screw (11).
3. Unscrew packing gland and remove valve stem assembly. The packing washer (4) will usually come out with the stem assembly and, rarely, the packing (3) and bottom washer (2). Any of these items which are left in the valve body are removed in the next step.
4. Using the Carr Lane 4-ball locking pin (-3 size) as a packing puller remove the packing and washer(s) from the valve body.
5. Discard the packing (3) and replace with a new one. If this is not possible, trim off the extruded packing material.
6. Remove the handle (13).
7. Disassemble the stem by removing the two lock nuts (9).

Note: Item numbers appearing in parentheses refer to the following drawing of the Autoclave 30VM valve.

HS-5050-74

Disassembly, Inspection, Cleaning and Assembly, continued

Inspection and Cleaning

8. Inspect the stem (6). If the seating area is badly deformed, replace the stem. If the packing seal area is scratched, polish the stem. If the scratches cannot be polished out, replace the stem.
9. Inspect the I.D. of the bottom washer (2). There is often a small burr at each end of the hole (possibly causing spiral scratches on the stem). These burrs can be removed by sliding the washer back and forth on a narrow strip of 600 grit sandpaper or comparable emery cloth passed through the hole.
10. Inspect the passages in the valve body and remove any chips or other foreign material.
11. Inspect the valve seat for excessive wear, scratches, cracks or burrs. Burrs can be removed with a small file or drill. if the seat is cracked, excessively worn or badly scratched, replace the valve body.
12. Wash all parts with acetone. If a very high cleanliness is required follow the acetone with several minutes in an ultrasound cleaner filled with Freon TF.

Note: Some magnification and a good light source is necessary when inspecting valves.

HS-5050-75

Disassembly, Inspection, Cleaning and Assembly, continued

Assembly

13. Apply a thin film of KOPR-KOTE thread lubricant to the following during assembly:
    - Both sides of both thrust washers (7)
    - The top section of the stem (6) where it fits inside the sleeve (8)
    - The threads on the bottom of the sleeve (8)
    - The packing gland (5), coating the threads and the bottom surface where it will contact the packing washer (4).
14. Assemble stem assembly (6), (7), (8), (9); lock nuts (9) need only be finger tight at this time. Screw the packing gland (5) all the way onto the sleeve (8). Slide the packing and washers (2), (3), (4) onto the stem.
15. Insert the stem assembly into the body and, ensuring that the stem is fully backed out, torque the packing gland to between 45 and 50 ft-lbs. Wait 5 minutes and, without breaking the packing gland loose, reseat it to the same torque.
16. Install the locking device (10).

HS-5050-76

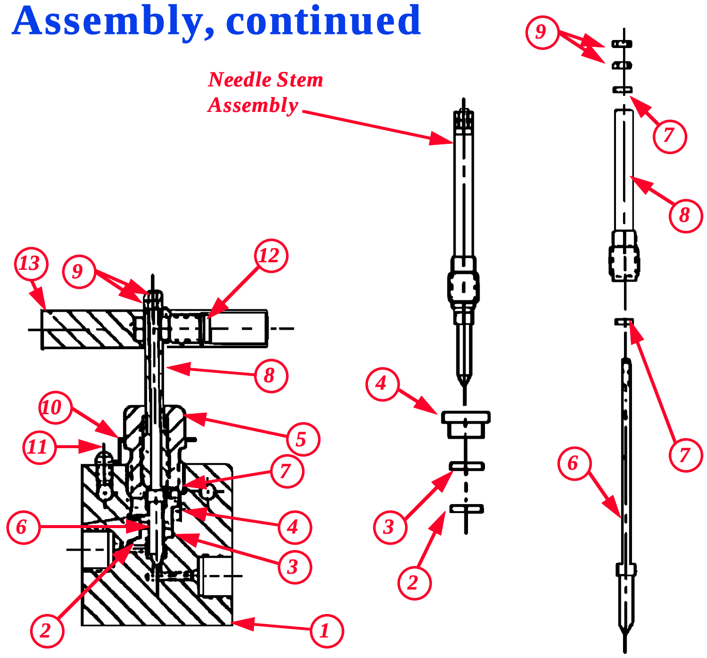
Disassembly, Inspection, Cleaning and Assembly, continued

Assembly, continued

17. Install the handle (13), taking care that it does not bind on the thrust washer (7) or the lock nuts (9).
18. Using the lock nuts (9), adjust the torque on the floating stem. Torque should be set such that the floating stem will not turn at the same rate as the handle. An ideal setting to minimize backlash is 1/2 turn of the stem for each full turn of the handle.
19. Work the stem into the seat gradually. Close and open the valve 5 or 6 times, gently at first and building up to normal closing force (generally about 3 to 4 ft-lbs).
20. Recheck the torque adjustment of the floating stem, as in step 18.

HS-5050-77

Disassembly, Inspection, Cleaning and Assembly, continued



	Parts List
1	Body
2	Bottom Washer
3	Packing
4	Packing Washer
5	Packing Gland
6	Stem
7	Thrust Washer
8	Sleeve
9	Lock Nut
10	Locking Device
11	Screw, #10-24
12	Set Screw, 3/8" - 16
13	Handle

HS-5050-78